CORS & OPUS WORKSHOP
(Continuously Operating Reference Stations)

Presented by:
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NOAA's National Geodetic Survey

Michigan Great Lakes
Regional HtMod Meeting
Lansing, MI
March 17, 2009

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Ocean Service
National Geodetic Survey

Positioning America for the Future

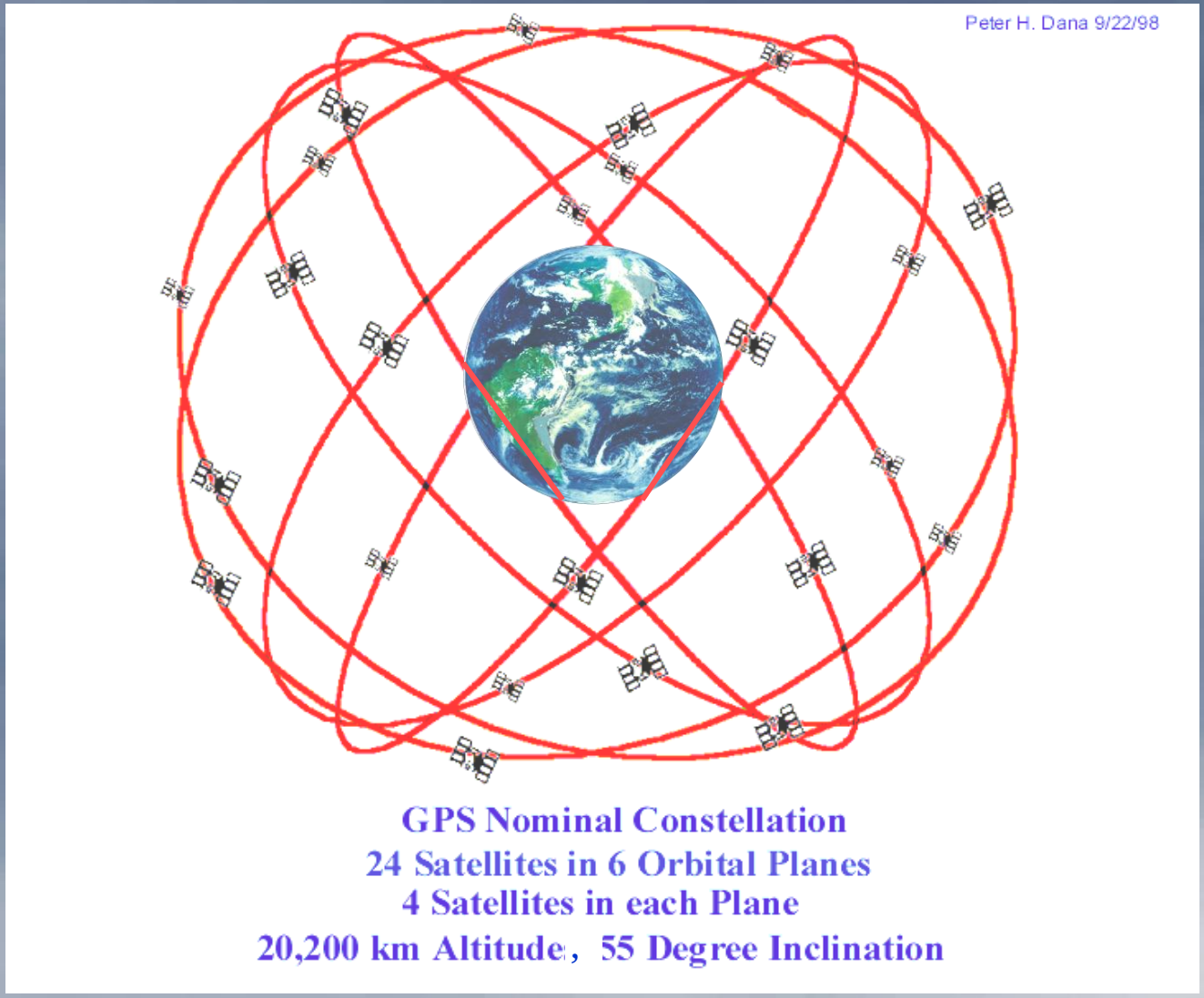
CORS Information

Web site: http://www.ngs.noaa.gov/CORS

Email: ngs.cors@noaa.gov

Telephone: 301-713-3563

Global Positioning System
GPS

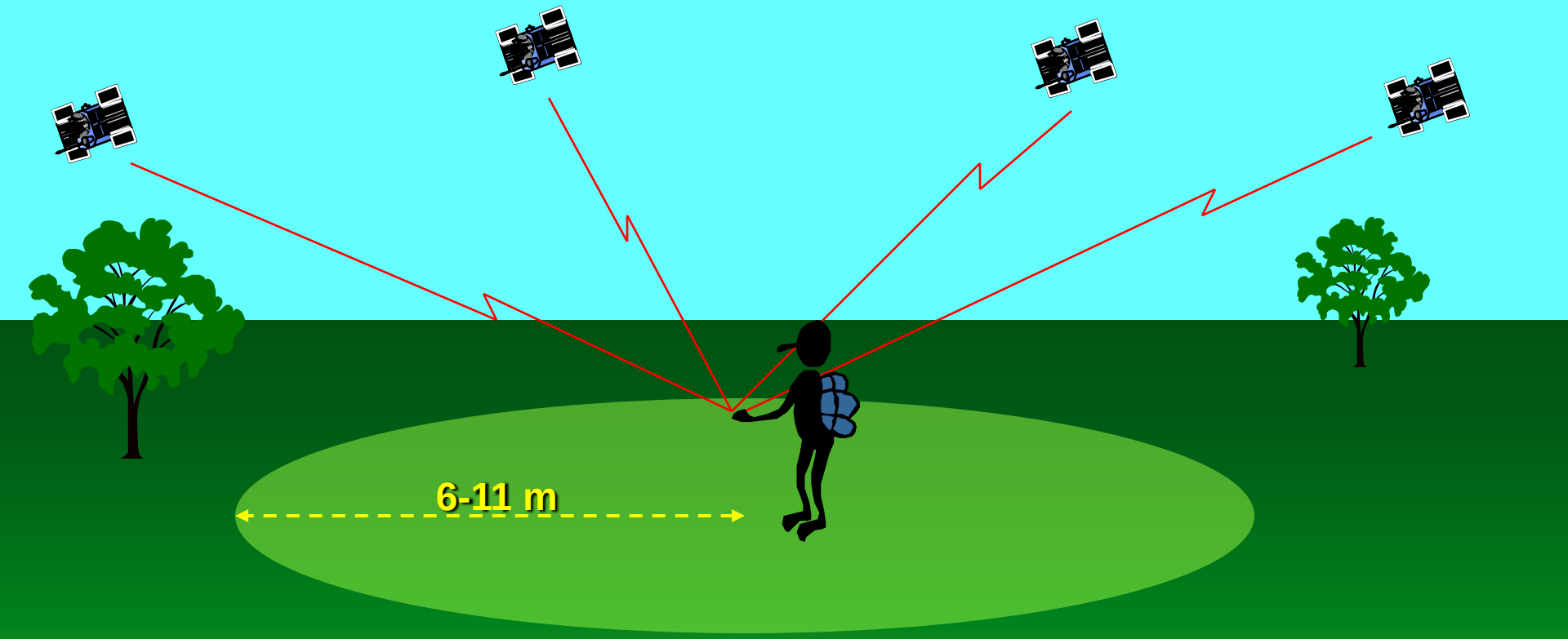


GPS Satellite

The Macrometer V1000 -- the first GPS receiver owned by NOAA!!

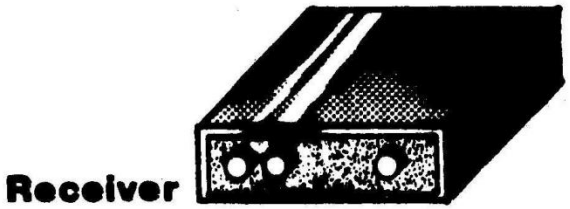
The GPS Pathfinder – puts a whole new spin on WHEN and WHERE!!

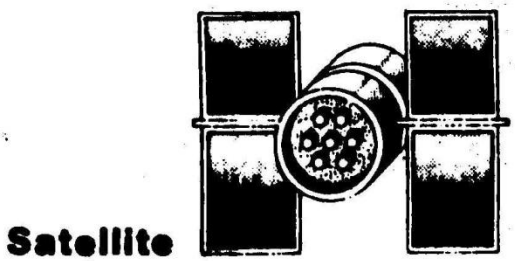
Standalone Positioning: Since May 1, 2000

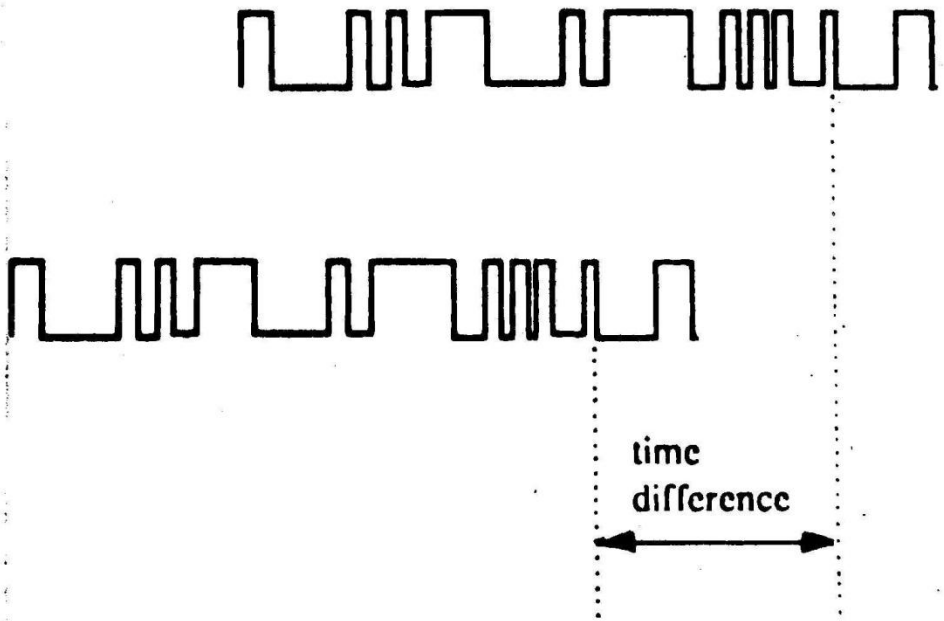


- C/A Code on L1
- No Selective Availability

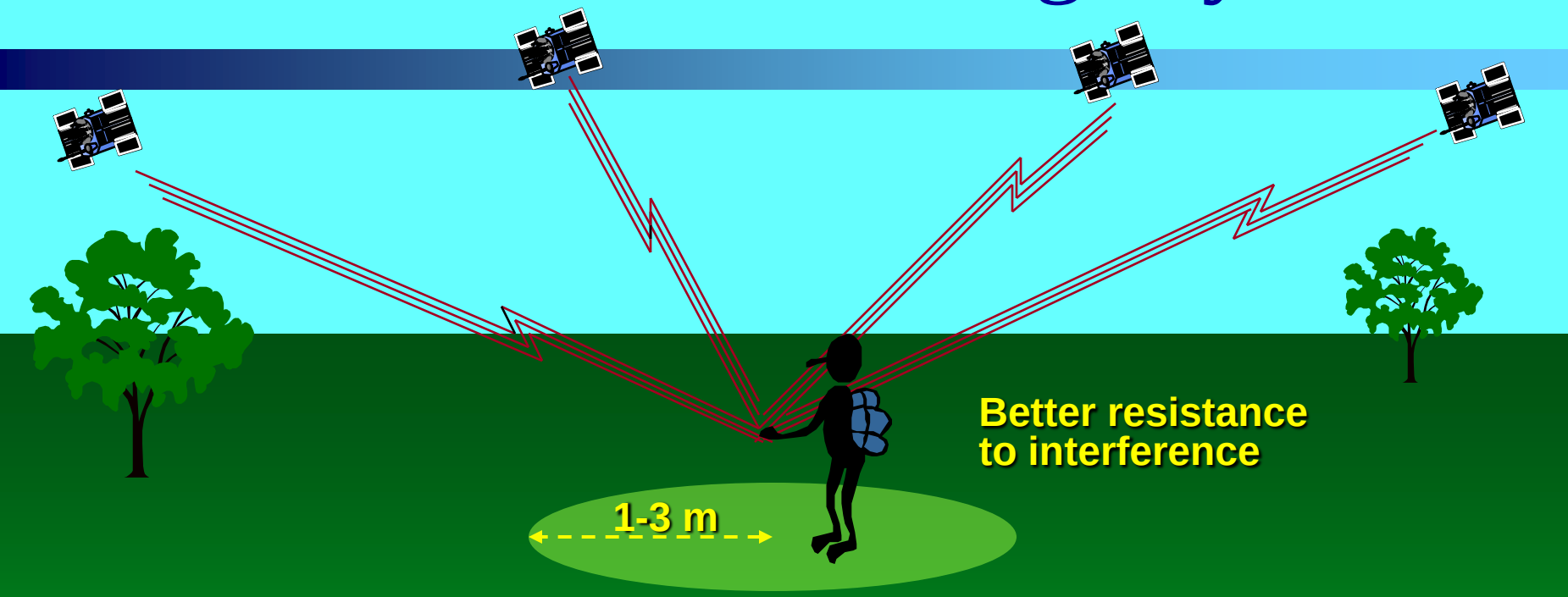
PSEUDORANGE FROM CODE DATA







Standalone Positioning: By 2011

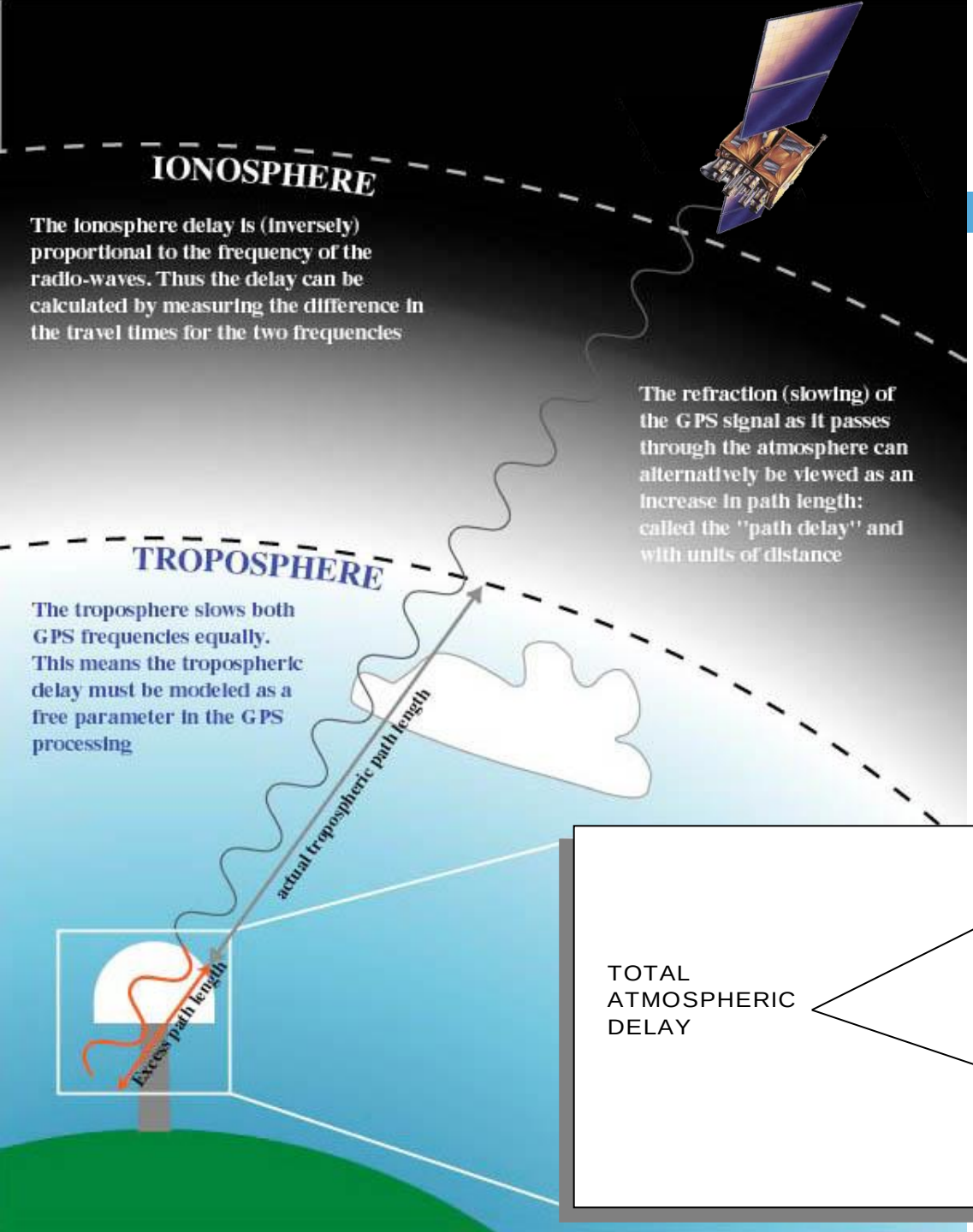


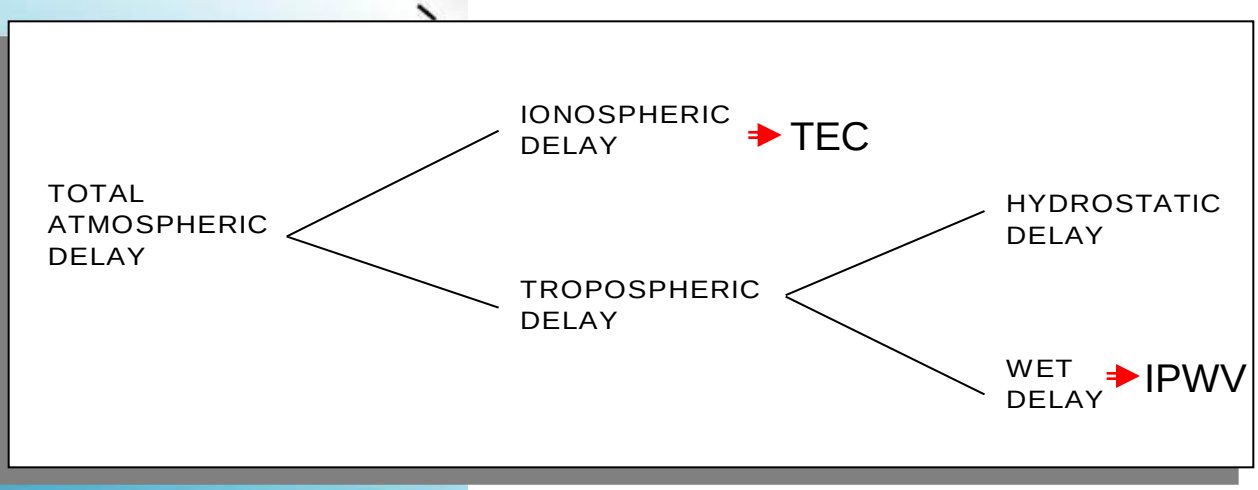
- C/A Code on L1
- L2C Code on L2
- New Code on L5

GPS ERROR SOURCES

* Receiver clock error
* Satellite clock error
* Satellite orbit error
* Ionospheric delay
* Neutral atmosphere delay
* Multipath
* Receiver noise

GPS Signal Delays Caused by the Atmosphere





Signal Multipath

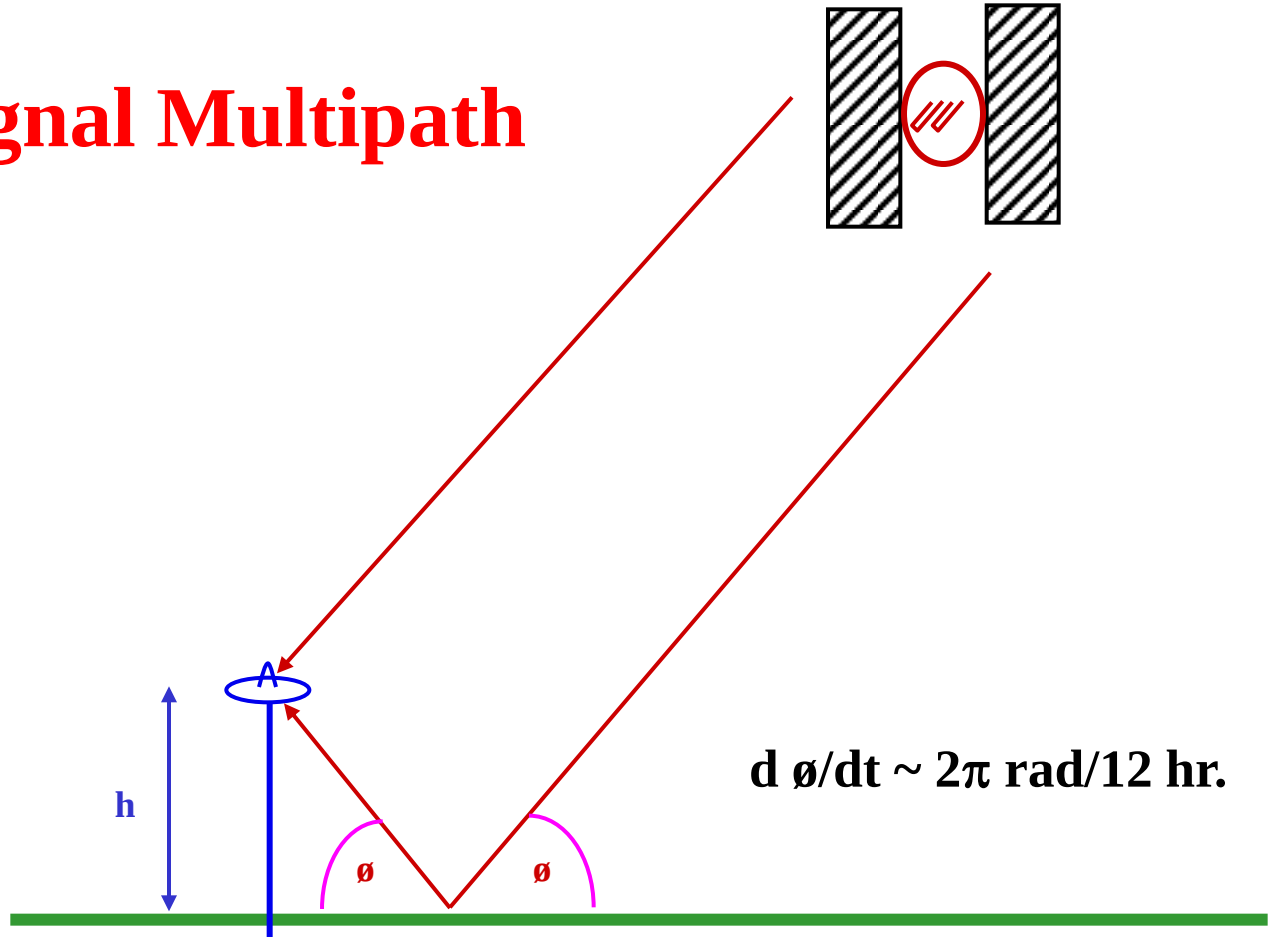
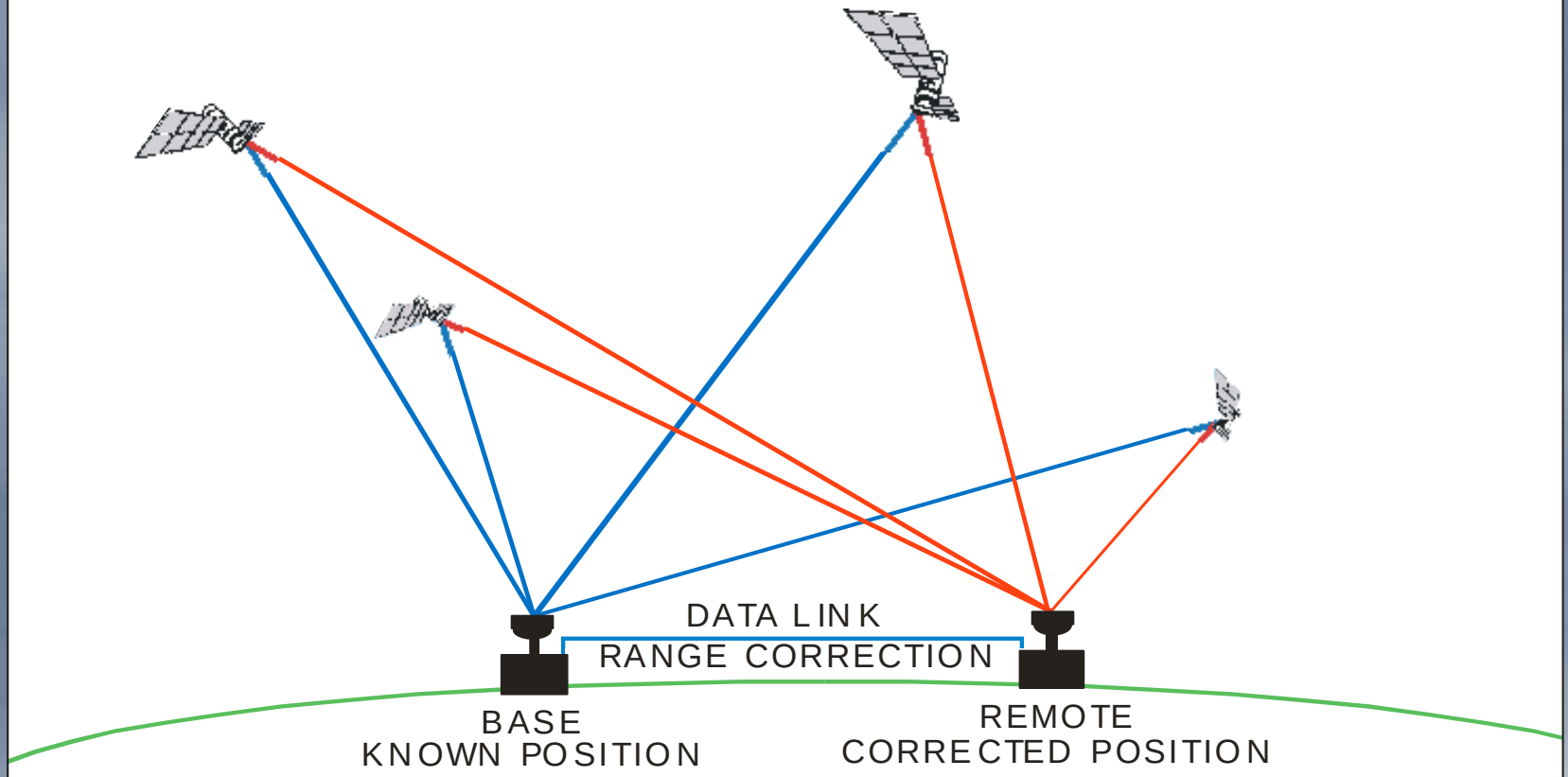


Figure 1
Multipath Description

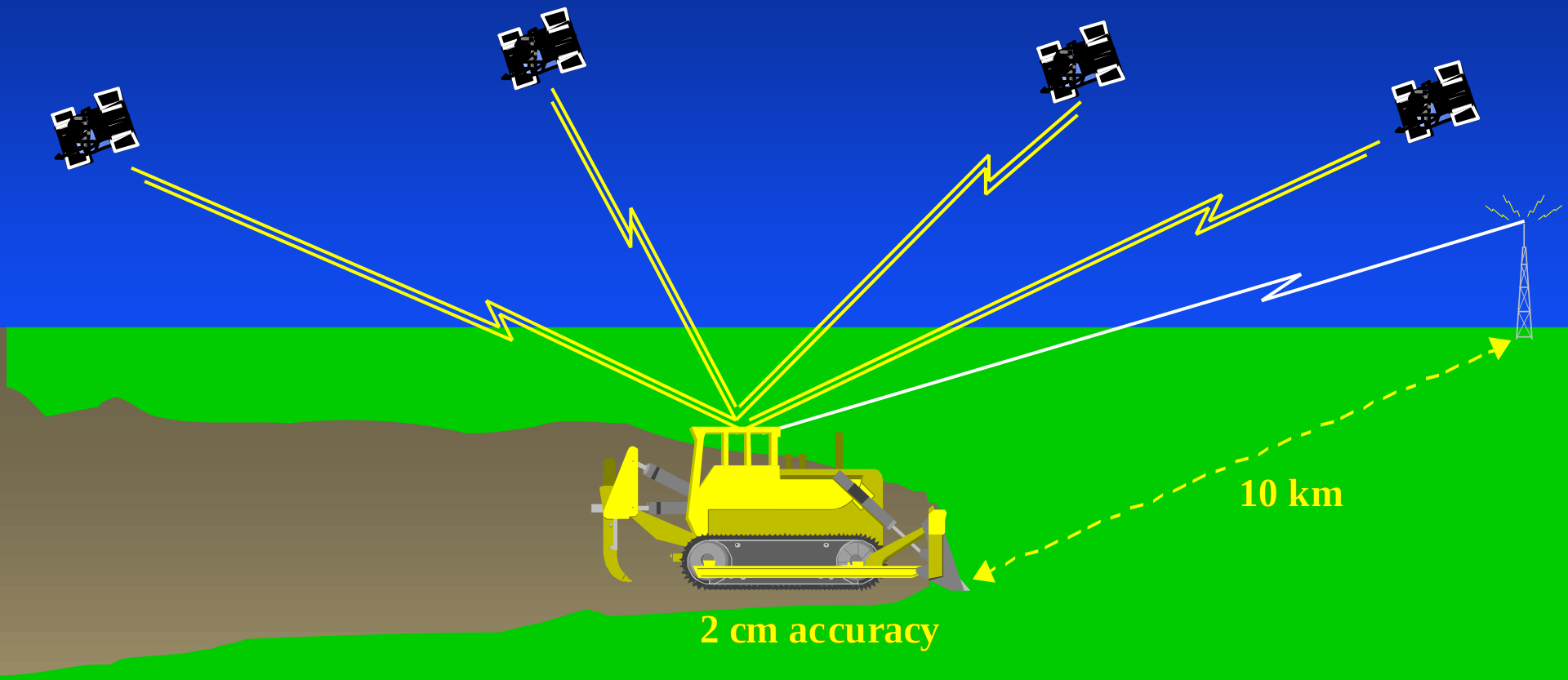
August 1987 -Ionospheric refraction and Multipath Effects in GPS Carrier Phase Observations
Yola Georgiadou and Alfred Kleusberg
IUGG XIX General Assembly Meeting, Vancouver, Canada

DIFFERENTIAL GPS POSITIONING



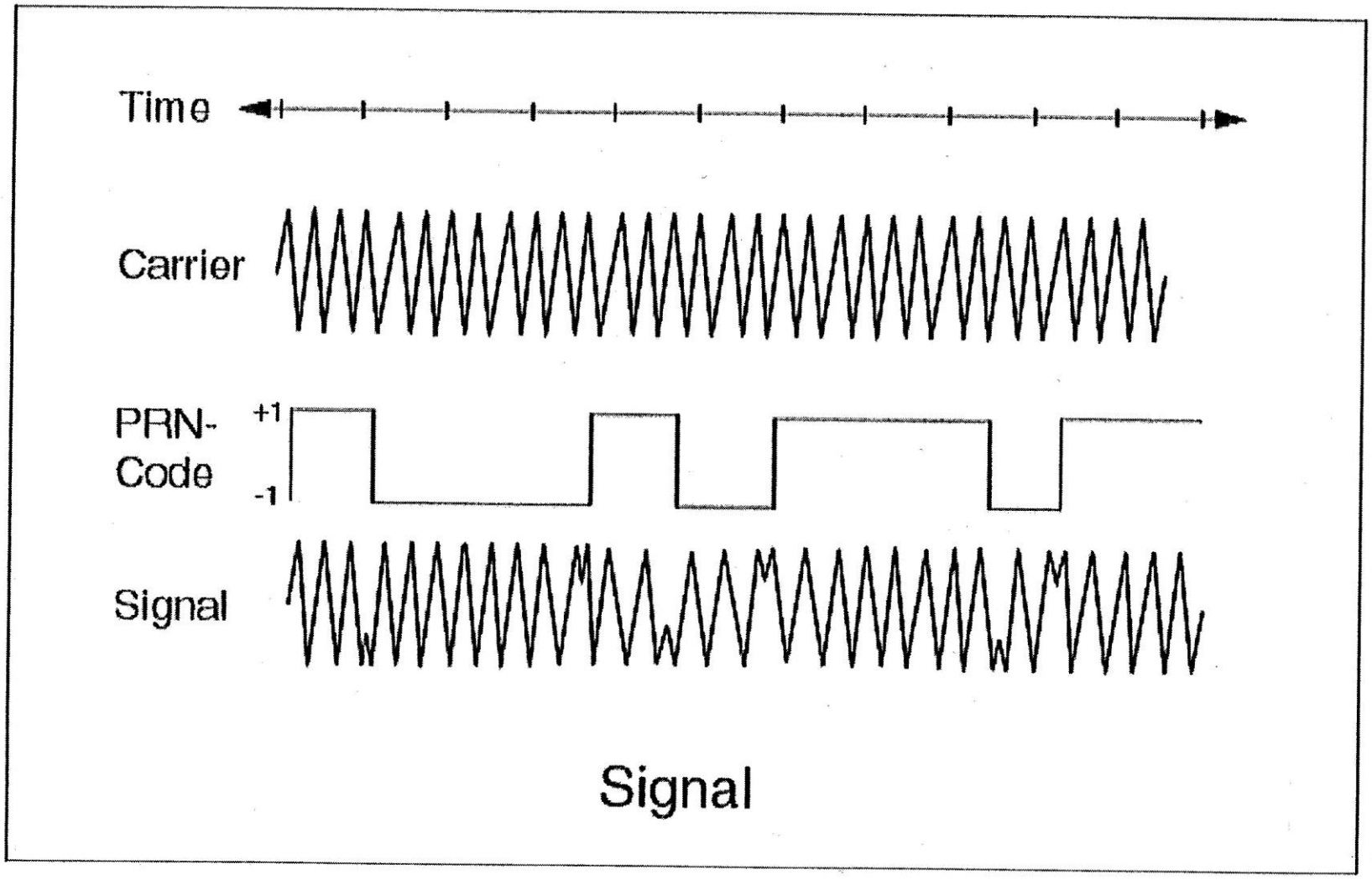
P H DANA 10/92

Real-Time Kinematic: Today

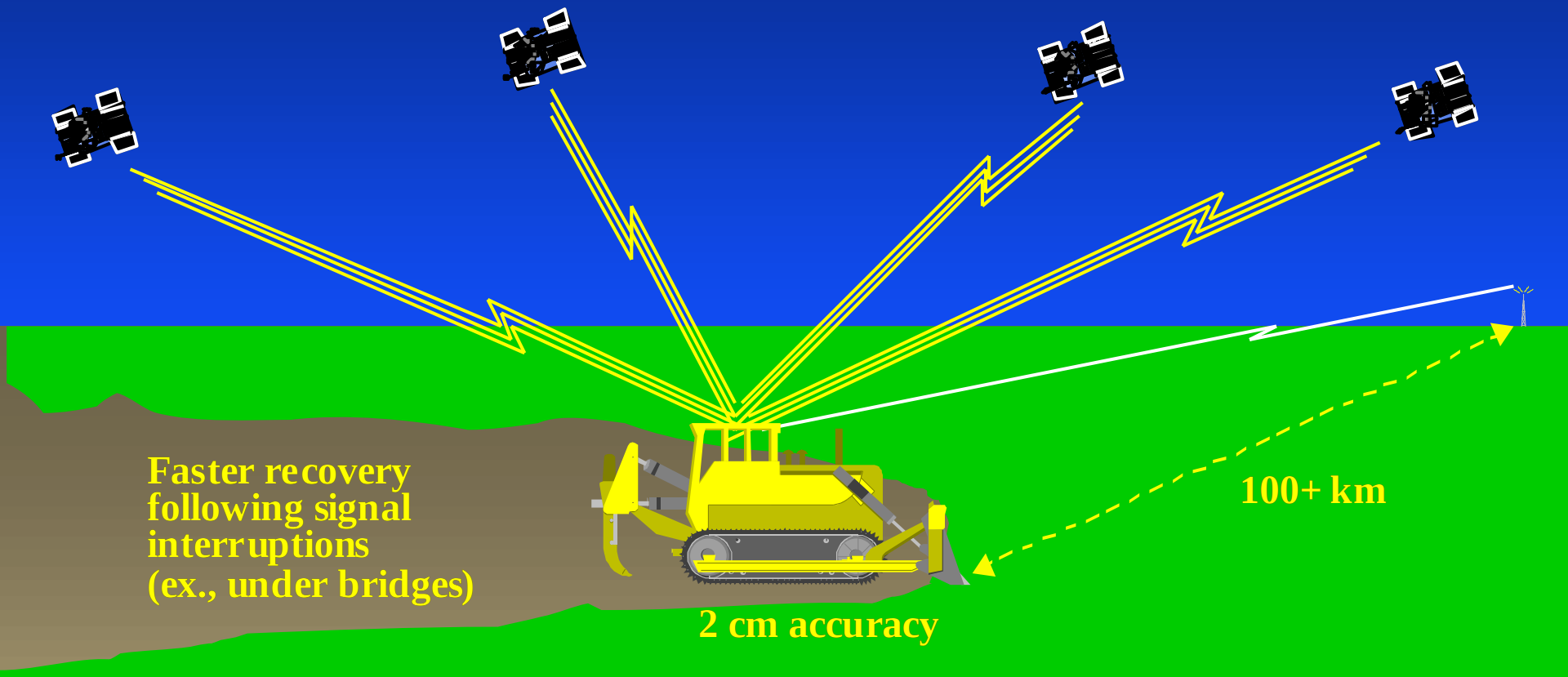


- L1 Code and Carrier
- L2 Carrier
- Data Link

CARRIER MODULATION



Real-Time Kinematic: Tomorrow



- L1 Code and Carrier
- L2 Code and Carrier
- L5 Code and Carrier
- Data Link

HOW TO ACHIEVE CM-LEVEL ACCURACY FOR BASELINES LONGER THAN 25 KM

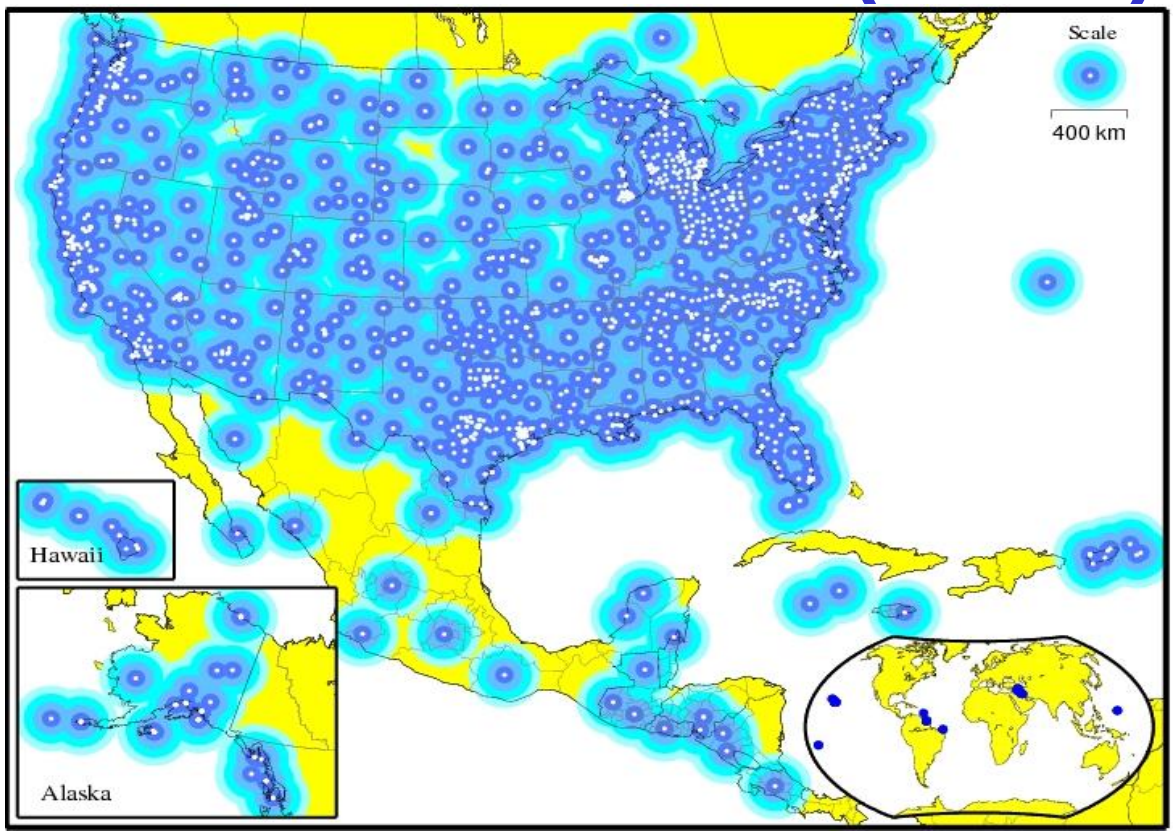
* OBSERVE FOR OVER 15 MINUTES

* USE DUAL-FREQUECY RECEIVERS

* POSTPROCESS GPS DATA WITH
  SOPHISTICATED SOFTWARE
  - USE “PRECISE” IGS ORBITS
  - SOLVE FOR INTEGER AMBIGUITIES
  - SOLVE FOR TROPO DELAYS

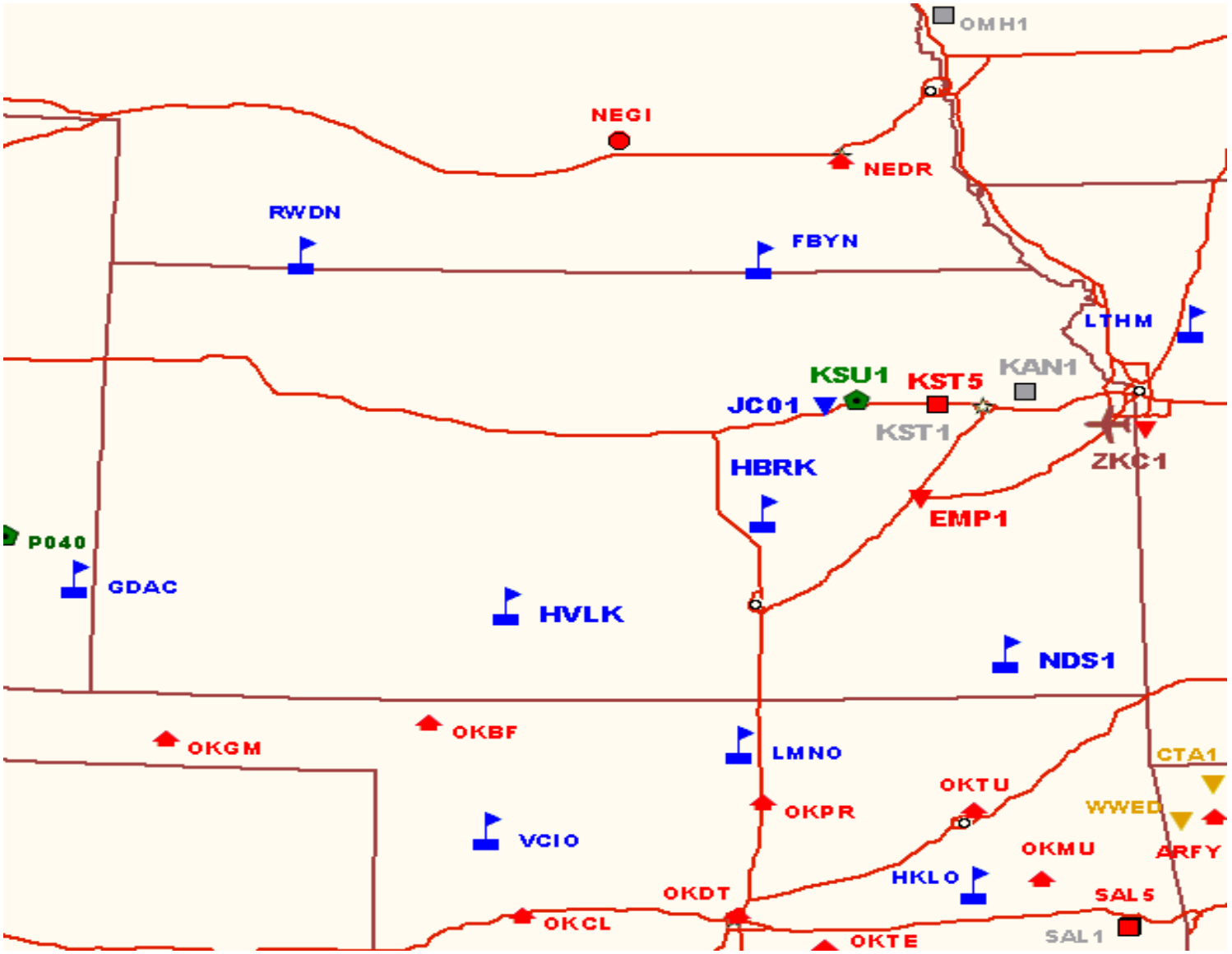
Vertical Precision Using Dual-Frequency GPS Carrier Phase Observations 95% Confidence Level

Continuously Operating Reference Stations (CORS)

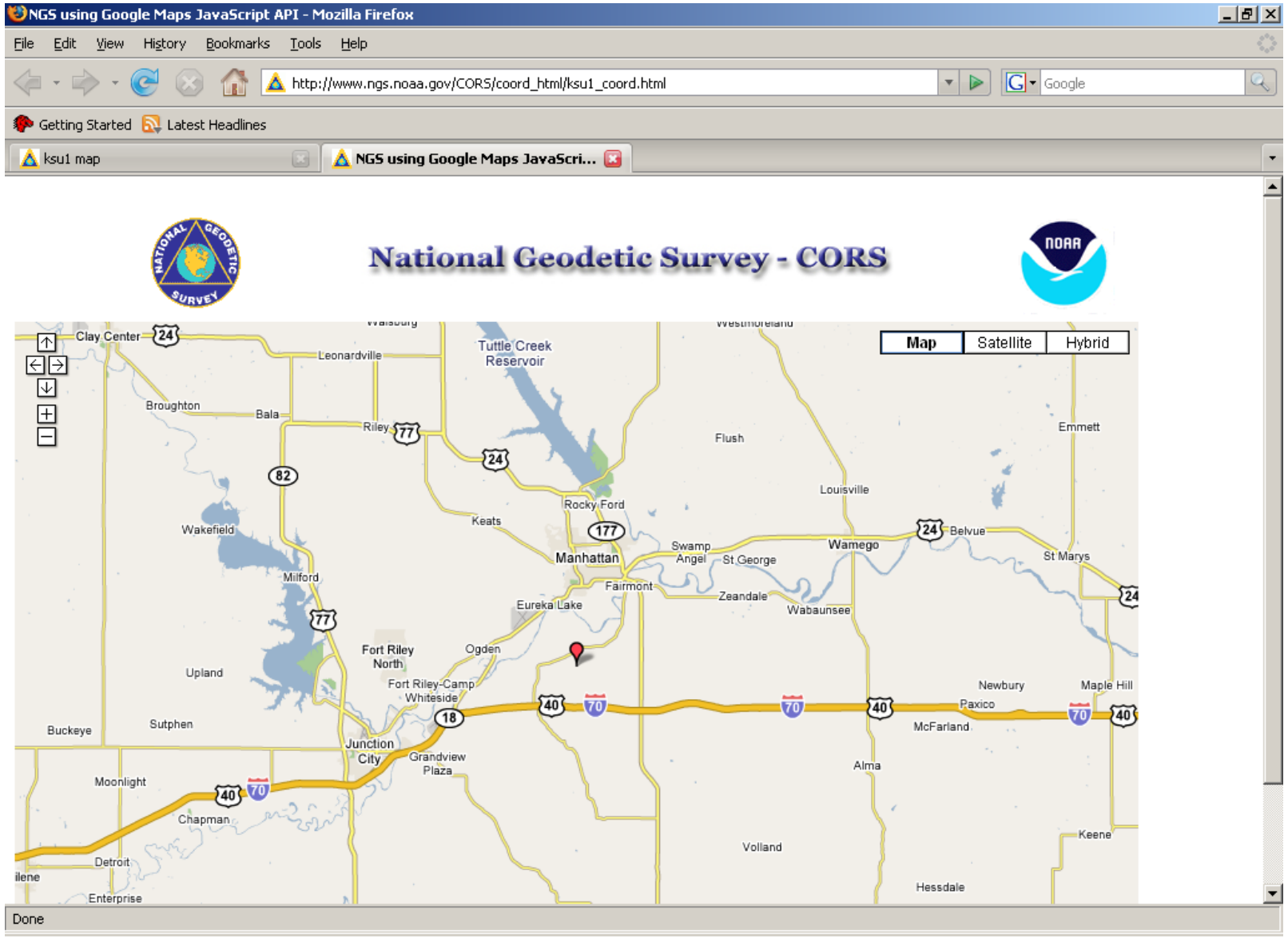


The CORS network enables differential GPS positioning with accuracies from 1 to 10 centimeters, or better.

Regional CORS Coverage



Local CORS Coverage – Manhatten (KSU1)



CORS SITES

CORS SITES

CORS OVERVIEW

- Network contains ~1,300 sites as of March 2009
- Growing at rate of 200 sites per year
- More than 200 organizations participate in the CORS program
- Provides code range (C/A, P1, P2)
  - and carrier phase observations (L1, L2)

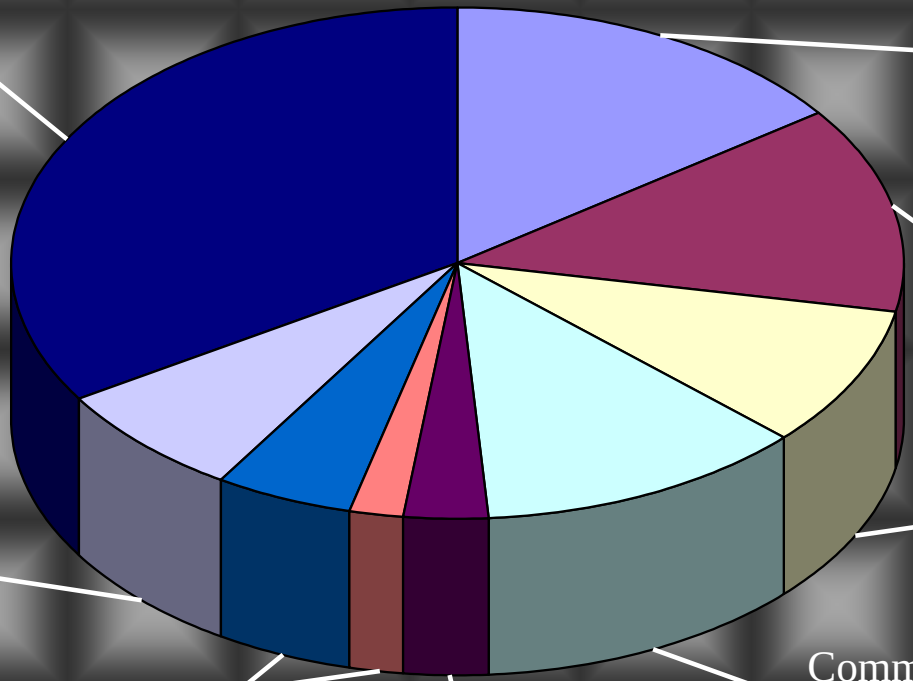
CORS APPLICATIONS

- Postmission Static Positioning (few cm-level accuracy with 15minutes of data, few dm-level accuracy with one minute of data)
- Postmission Kinematic Positioning (dm-level accuracy for an aircraft, a boat, or a land vehicle)
- Geophysics / Crustal Motion
- Meteorology / Water Vapor in Atmosphere
- Space Weather / Free Electrons in Ionosphere

NATIONAL CORS NETWORK

- CORS information is available directly from NOAA's National Geodetic Survey in Silver Spring, MD
- GPS data stored in RINEX format
- Data made available to public via:
  - World Wide Web
  - File transfer protocol
- Currently 15 years of CORS data are online for immediate access
- Parallel CORS Data Facility being operated by NOAA's National Geophysical Data Center in Boulder, CO

CORS Partners



State Governments 34%

USCG / Surface Navigation 15%

NSF & Universities / Crustal Motion 13%

Local Governments 9%

Commercial 12%

Academic 3%

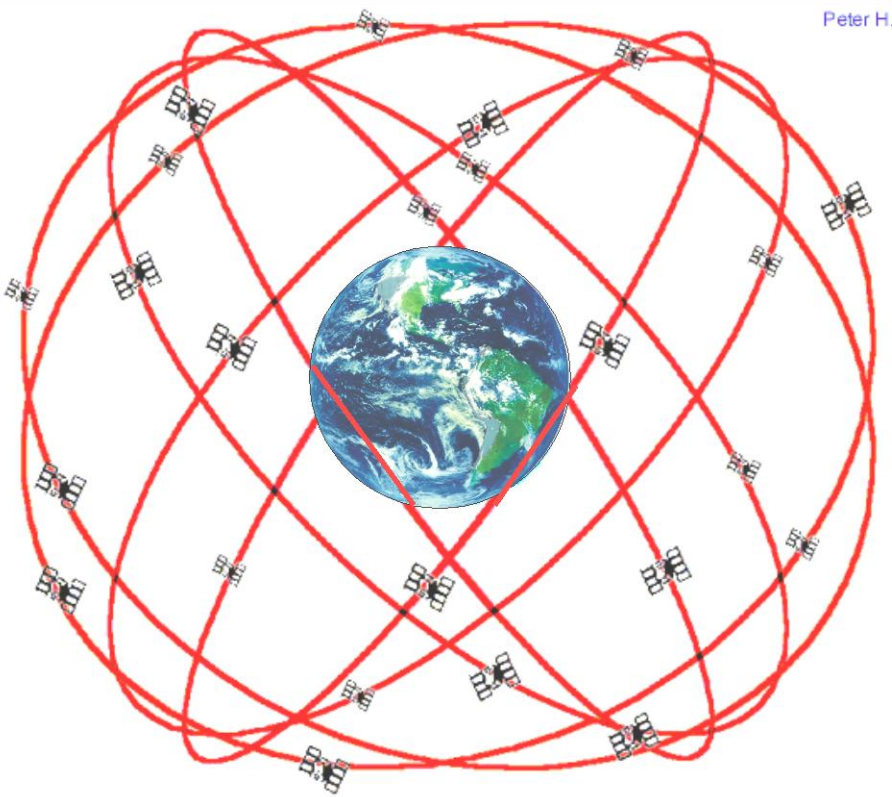
Foreign 2%

FAA, NASA & other Fed'l Gov 5%

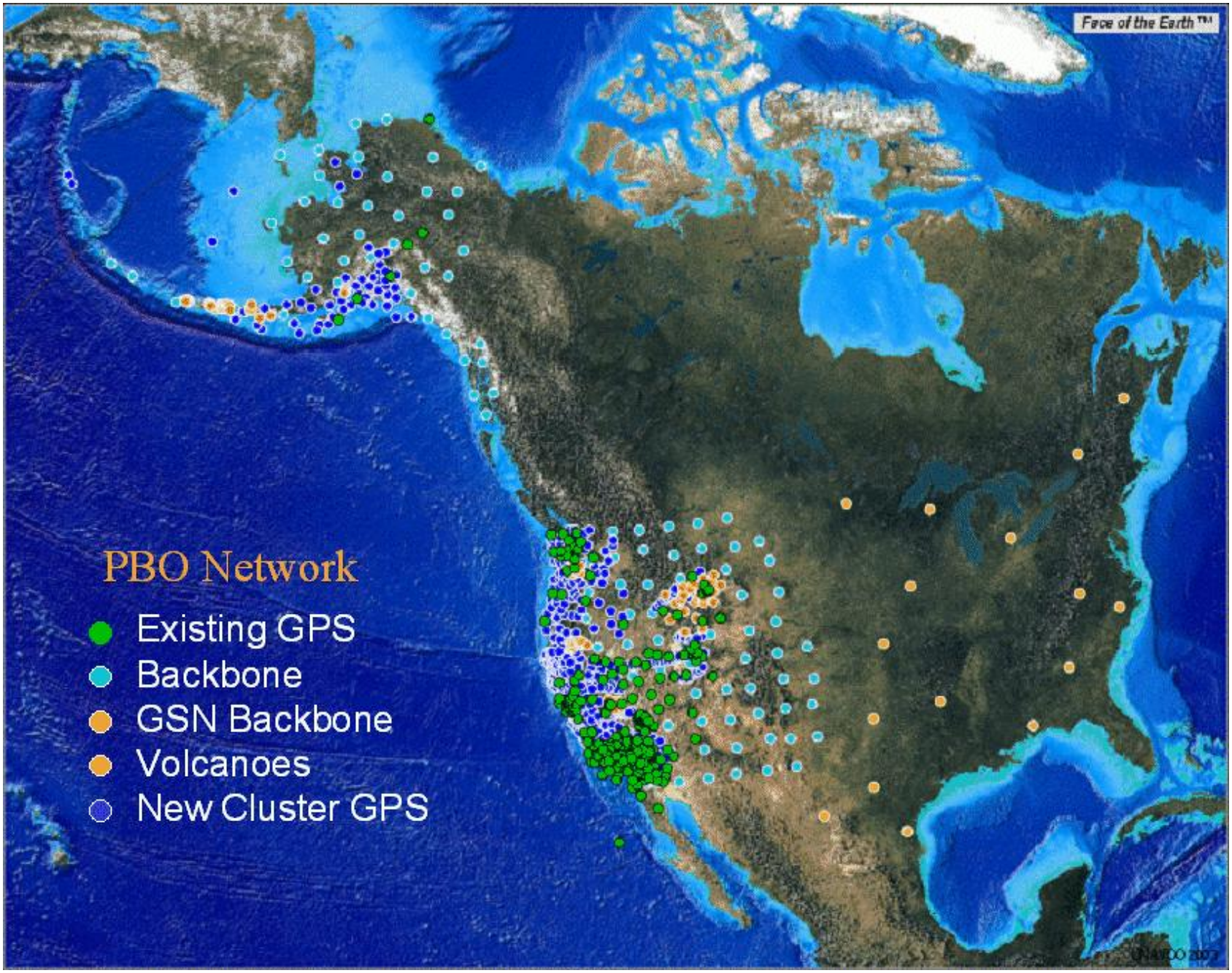
NOAA / Geodesy & Meteorology 7%

CORS PARTNERS: FEDERAL

- *Federal Highway Administration*
- *Federal Railway Administration*
- *Federal Aviation Administration*
- *Forecast Systems Laboratory*
- *National Geophysical Data Center*
- *NASA*
- *US Geological Survey*
- *US Army Corps of Engineers*
- *US Air Force*
- *US Naval Observatory*



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitude, 55 Degree Inclination


Face of the Earth™
PBO Network
Existing GPS
Backbone
GSN Backbone
Volcanoes
New Cluster GPS

CORS PARTNERS: INTERNATIONAL

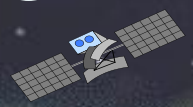
CORS Partners: Private Industry

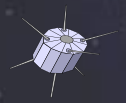
" If you want to see where GPS is going, then keep your eye on the GPS manufacturers."

Bill Strange
Former Manager
National CORS Program

Many GPS companies have developed software that provides their customers with automatic access to CORS data for postprocessing activities.

Civil GPS Use





Satellite Ops -- Ephemeris, Timing

Power Grid Interfaces

Personal Navigation

Trucking & Shipping

Surveying & Mapping

Aviation

Recreation

Communications -- Network Synchronization and Timing

Railroads

Fishing & Boating

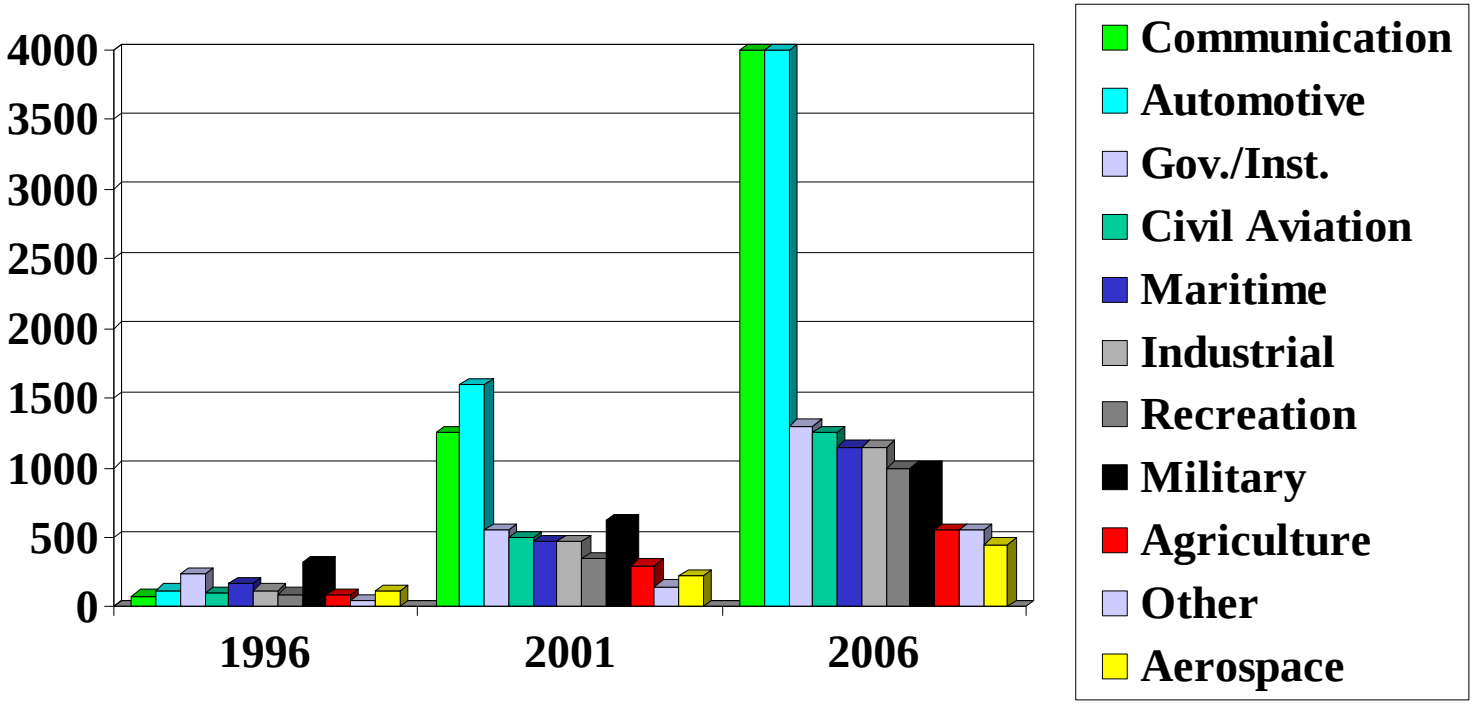
Off shore Drilling

97-0025

Consumer/Recreational

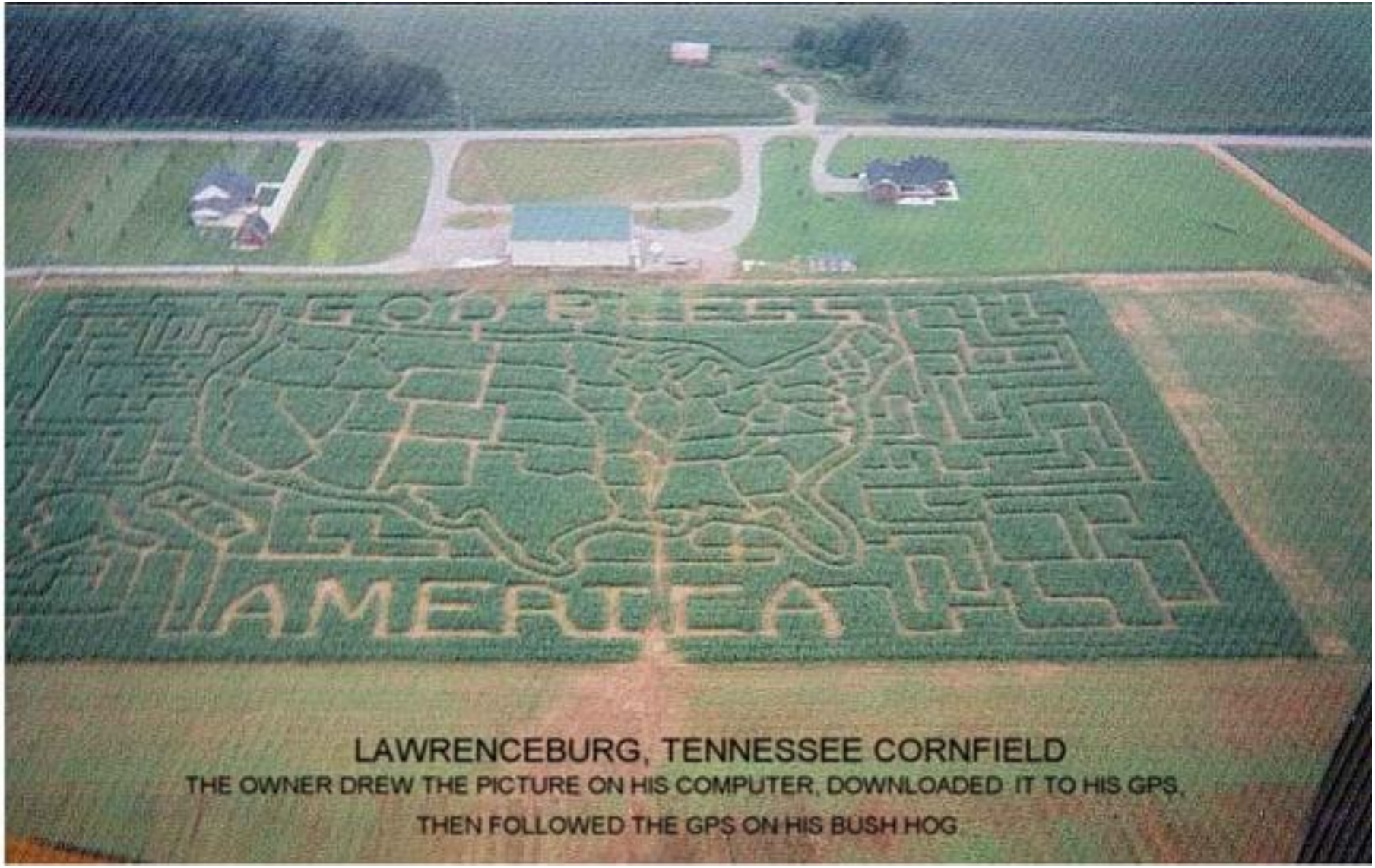
- $3.8B market by 2003
- Portable receivers for fishermen, hunters, campers, hobbyists, etc.
- Recreational facilities
- Estimated 40M potential users in the U.S. alone
- Highly elastic demand
- Integration of GPS into cellular phones expected to generate huge volume

Future GPS User Sectors - $M
(Freedonia Group Report - 1997)

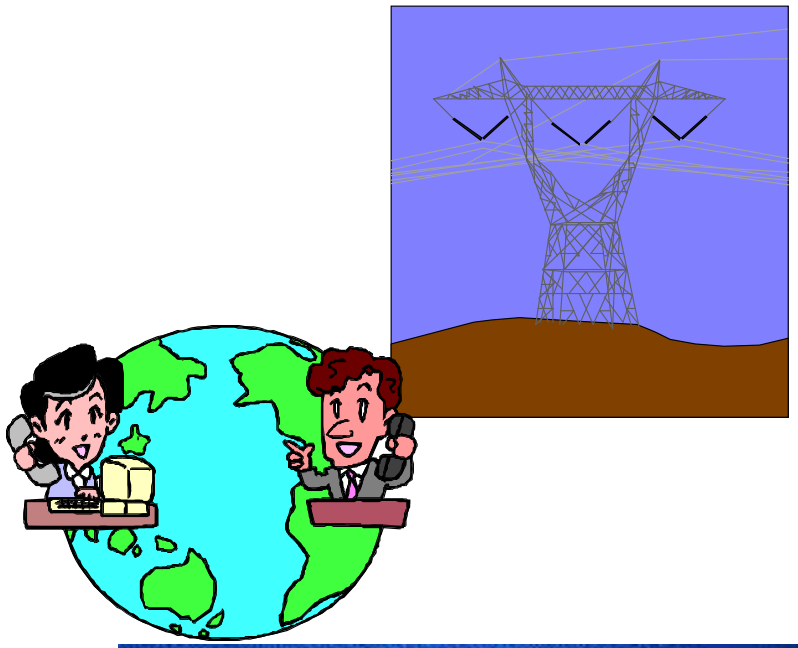


Sales of GPS Equipment & Services

Precision Agriculture

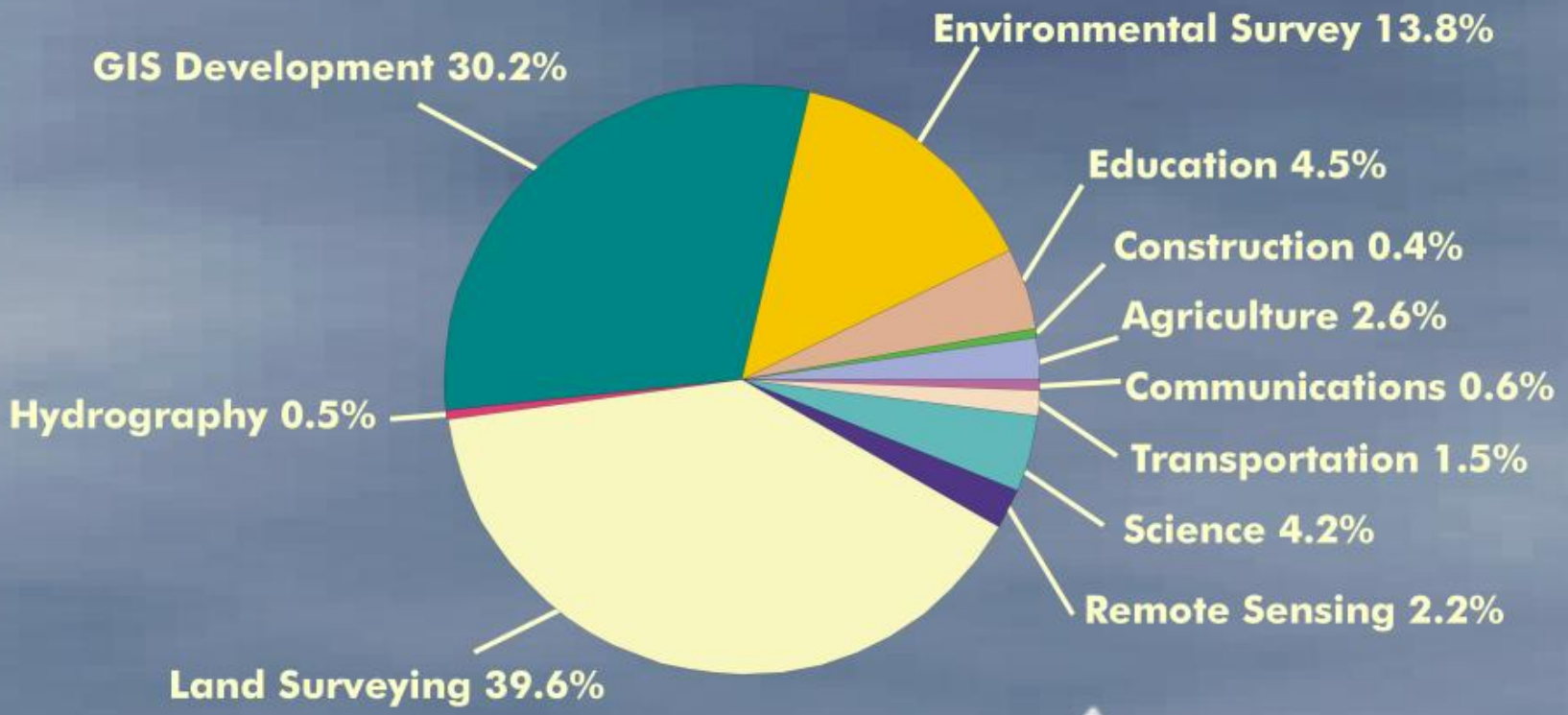


Timing Applications



- Some estimate the timing market at $40-100M
- Communications network synchronization and management
  - Phone, wireless systems
  - LANs, WANs, Internet
- Power grid management and fault location
- Financial transactions
- E-commerce signatures

CORS Applications



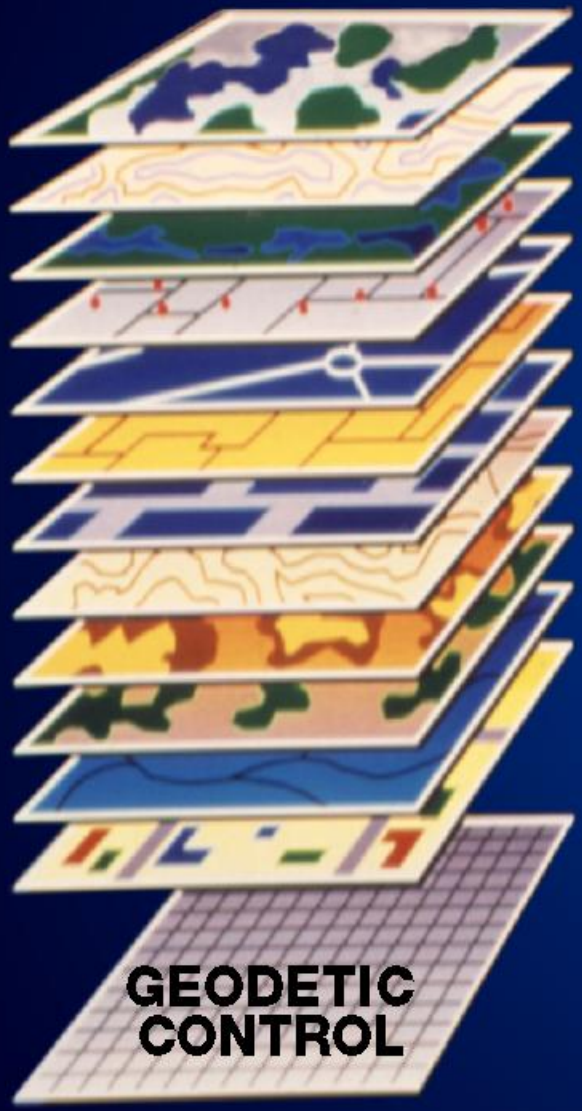
5,646
Survey responses
Fall 1999

CORS Supports Precise Positioning

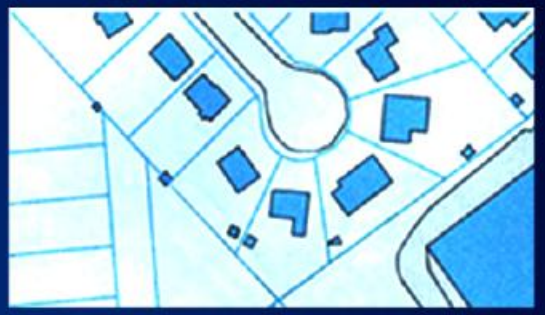
Before CORS: Accurate differential GPS positioning with multi-person field crew.

After CORS: Accurate differential GPS positioning with one-person field crew.

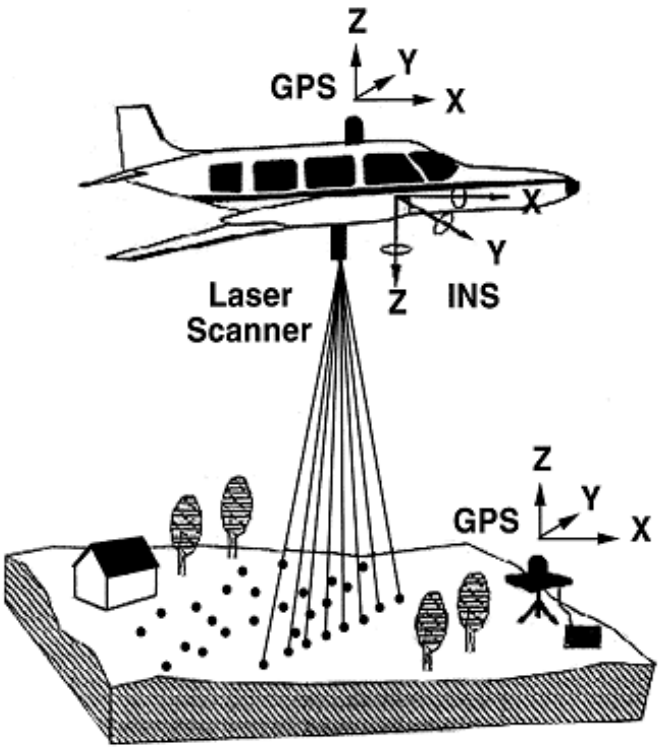
Geographic Information Systems (GIS)



Wards and Precincts
Demographics
Structures
Water Utilities
Sewerage
Electrical Utilities
Roads
Boundaries
Land Use
Hydrology
Soils
Topography



CORS Enables Users to Determine the Travel Path of a Moving Platform



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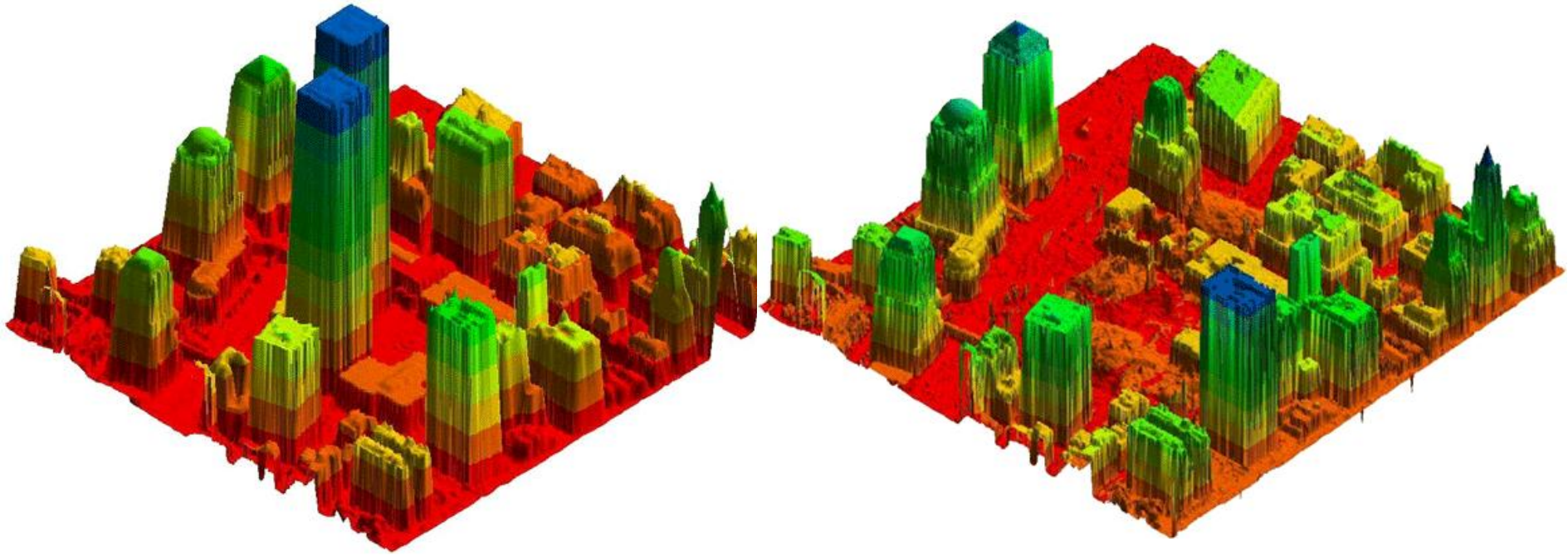
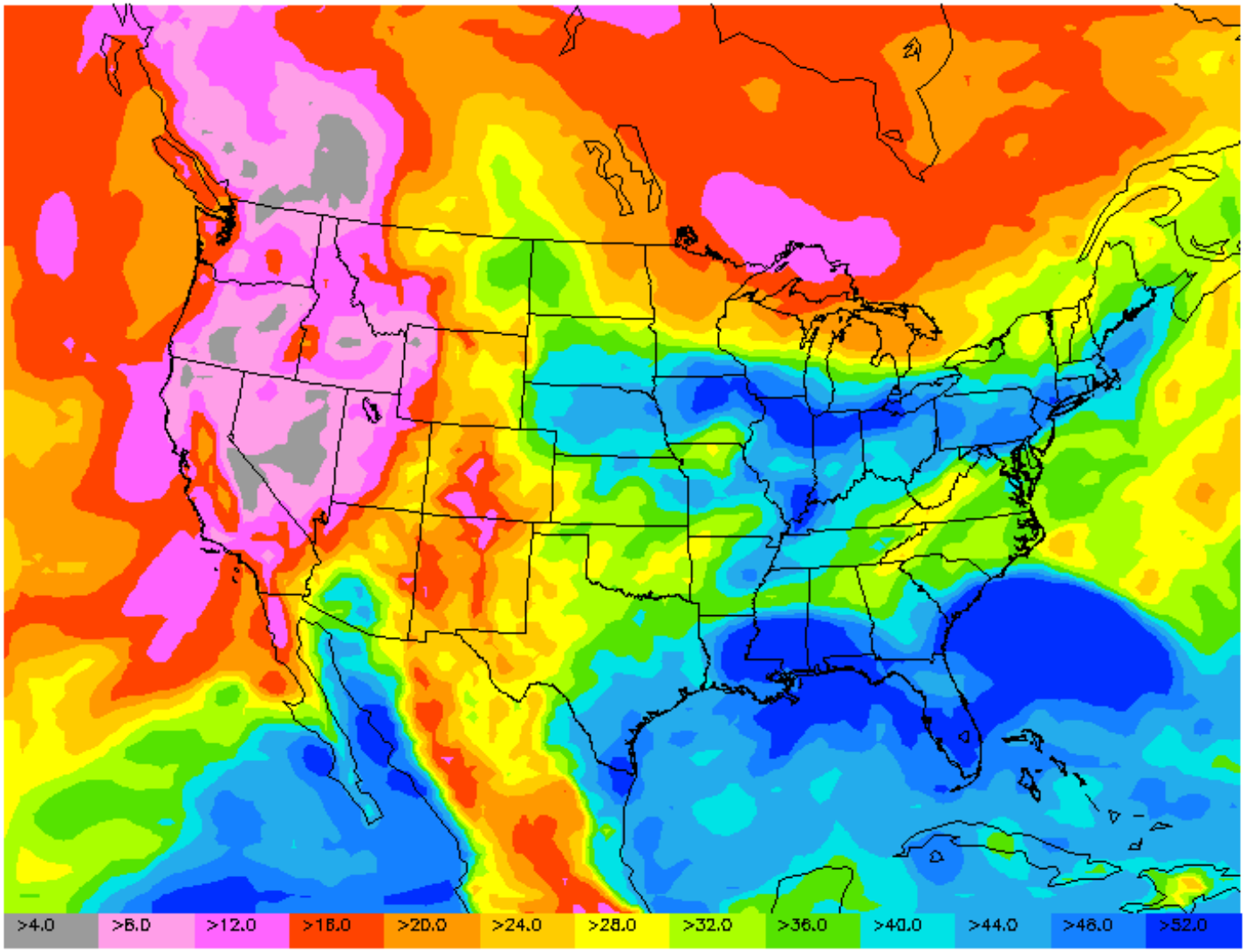
LIDAR images of Manhattan before and after 11 SEP 2001

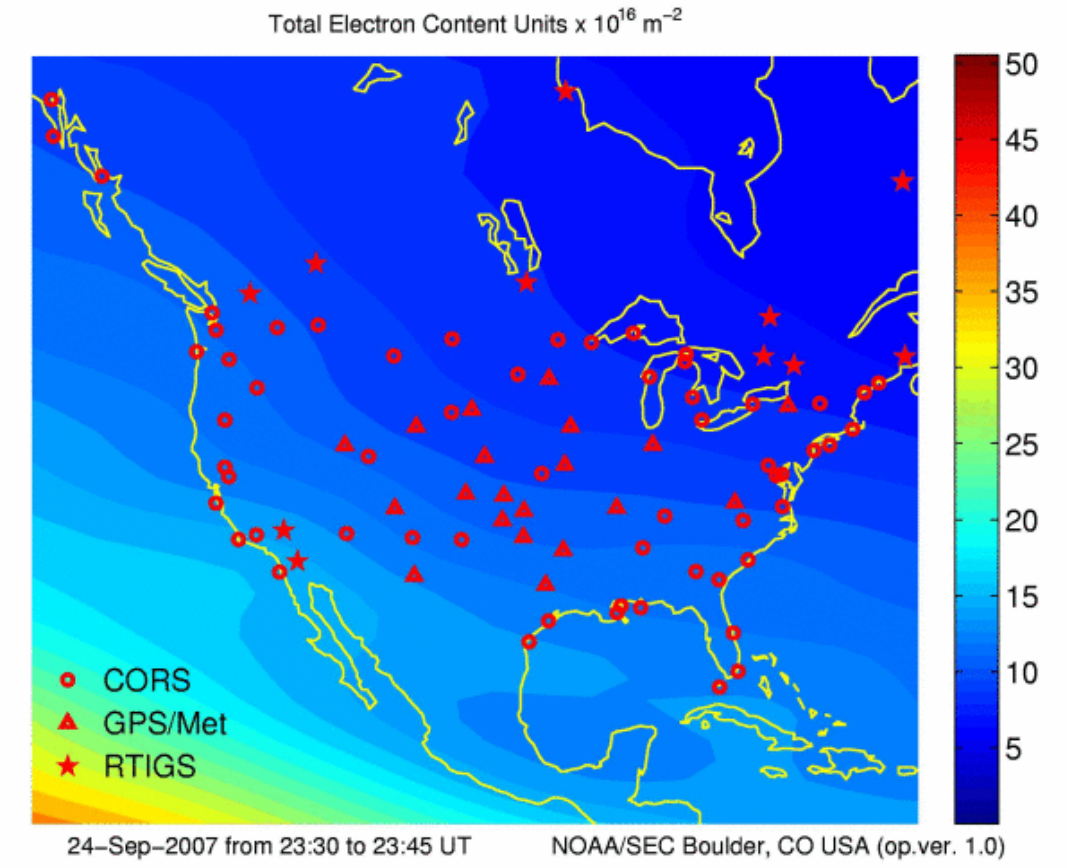


These images are computerized visualizations of elevation information of the World Trade Center from before (July 2000) and after (September 15, 2001) the attack. These maps were produced using an airborne LIDAR (Light Detection and Ranging) system. The LIDAR system creates detailed and highly accurate elevation information by the precise timing of thousands of laser pulses striking the ground surface. These data can be manipulated in the digital environment to create an array of maps and views of the project site and to obtain precise measuresments of structures, debris fields, and other vital information. These images were generated by EarthData (www.earthdata.com), and the aircraft was positioned using CORS data from the NJI2 site which is operated by the New Jersey Institute of Technology.

Hourly Forecast of Precipitable Water



CORS for Monitoring Space Weather



NOAA's Space Weather Prediction Center uses CORS data to map the distribution of free electrons in the ionosphere every 15 minutes.

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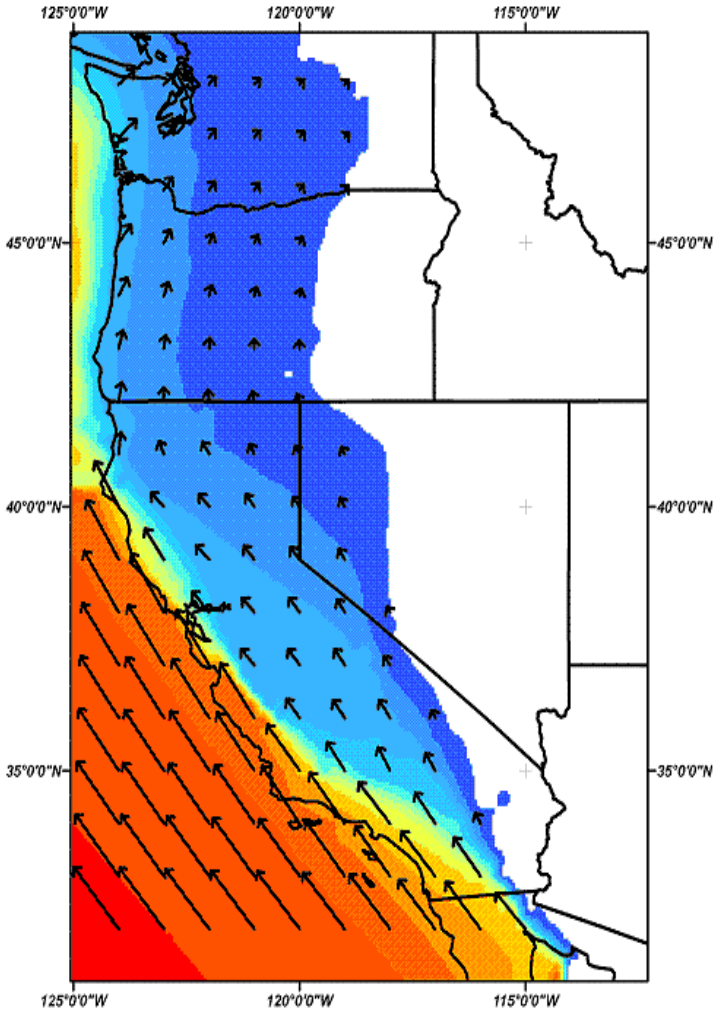
CORS for Monitoring Horizontal Crustal Motion

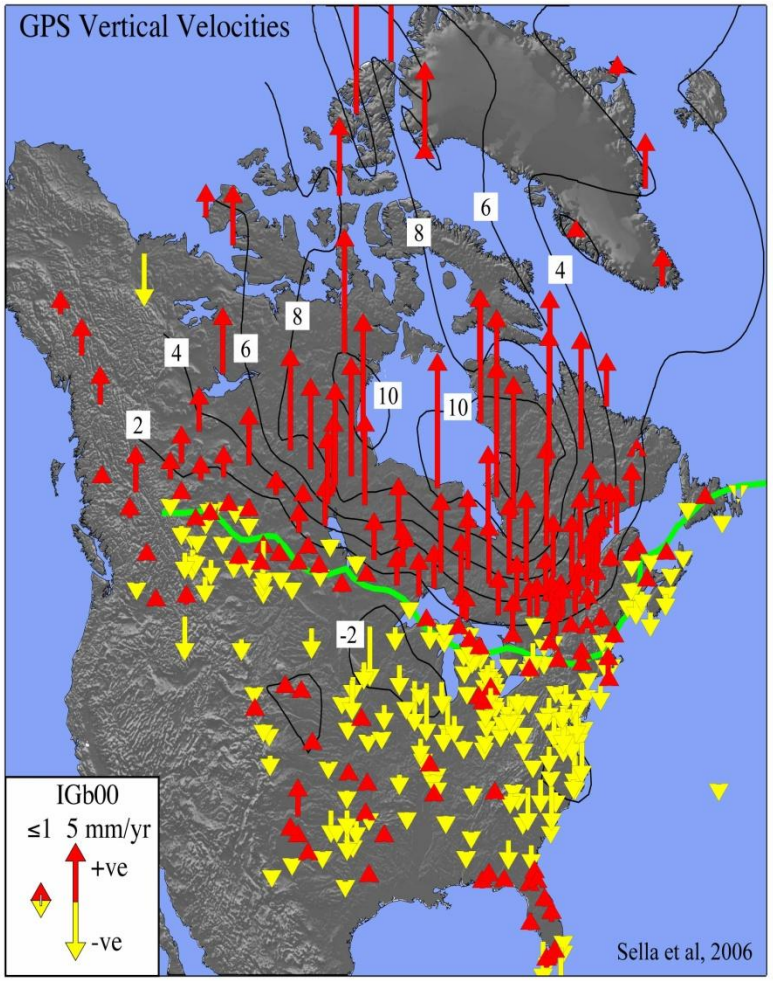


Horizontal velocities in the western U.S. relative to the North American Datum of 1983 as derived from geodetic observations.

Horizontal Velocities in mm/yr

- 0 - 4
- 4 - 8
- 8 - 12
- 12 - 16
- 16 - 20
- 20 - 24
- 24 - 28
- 28 - 32
- 32 - 36
- 36 - 40
- 40 - 44
- 44 - 48
- 48 - 52
- 52 - 56

CORS for Monitoring Vertical Crustal Motion



Vertical velocities associated with Glacial Isostatic Adjustment